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Original Articles

Climate change vulnerability in urban slum communities: Investigating household adaptation and decision-making capacity in the Indian Himalaya

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ABSTRACT

Climate change is predicted to have severe impacts on mountainous regions, including urban settlements, and livelihoods of the urban poor. Adaptive capacity for marginalized groups is largely determined by household-level resources and decision-making capacity. This study investigated the vulnerability status and prevalent adaptation strategies of urban slum dwellers in Dehradun, Indian Himalayas, using a pre-tested questionnaire covering household characteristics and indicators of vulnerability, in face-to-face interviews with the head of 122 randomly selected households in four slums. We found that overall vulnerability was very high, with very low absorptive and coping capacity for potential impacts of climate change. Moreover, vulnerability and coping strategies were socially differentiated in terms of the decision-making capability and resource capacity of households. Two groups per category (good and bad decision makers; poor and poorer households) were distinguished. The exposure dimension of vulnerability differed significantly by resource capacity and decision capability. However, the sensitivity dimension of vulnerability did not differ between the groups, while the adaptive capacity dimension of vulnerability differed depending on decision-making capability. In designing appropriate strategies for long-term disaster mitigation for urban slums, it is thus important to address slum socio-ecology and the capability and capacity of slum dwellers.

1. Introduction

More than half the world's population lives in urban areas and the proportion is predicted to grow to 66% by 2050 (UN-DESA, 2014). Three-quarters of the current urban population lives in low- and middle-income nations (IPCC, 2014). Rapid, uncontrolled and unplanned growth has led to the development of informal, heavily overpopulated settlements and slums, with slum populations growing from 767 million in 2000 to 828 million in 2010 (UN-Habitat, 2006; Unger and Riley, 2007). In India, 31% of the population lives in urban areas and 17% of the urban population (65 million people) lives in slums (Census of India, 2011).

Slum dwellers typically lack durable housing, access to safe water, access to sanitation, sufficient living area and secure tenure. They are the most deprived of the urban poor and the most likely to suffer from disasters (Un-Habitat, 2004). With no proper infrastructure, human waste in slum areas leads to rapid degradation of environmental and human health (Porio, 2011). Slums also lack protective infrastructure to help cope with the impacts of environmental degradation and climate change (Satterthwaite and Moser, 2008; Wekesa et al., 2011; Alcayna-Stevens, 2015).

In urban slum areas and mountainous regions, climate change will exacerbate e.g. health hazards, property loss and disruption to incomes (Hardoy and Pandiella, 2009; Seto et al., 2012; Mitlin and Satterthwaite, 2013; Béné et al., 2014), increasing residents' vulnerability to climate change (IPCC, 2014). Good knowledge of urban slum areas is needed to devise adaptive responses that strengthen climate change sustainability and urban resilience (Vale and Campanella, 2005; Lankao and Qin, 2011; IPCC, 2014). However, little is known about the impacts of climate change on the urban poor (Moser et al., 2010; IPCC, 2014).

Household-level vulnerability and adaptive capacity assessments aim to generate knowledge that can reduce exposure and sensitivity to hazards (Below et al., 2012; Saroar and Routray, 2012; Pandey et al.,

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2016). Proper adaptation strategies can effectively reduce vulnerability, i.e. improve the ability to avoid/recover from negative impacts of extreme events (Heltberg et al., 2009). Household well-being is multidimensional and linked to individual control over assets and livelihood strategies (Moser, 2006). Household livelihood strategy includes decision-making capability to accumulate and allocate assets and is influenced by external feedbacks and risks. Household-level decisions are shaped by individual, local, contextual and multi-scale factors (Adger et al., 2009) and can influence overall vulnerability and sustainability (Brown, 2011). In this context, household decision-making ability and assets are elements within a complex system of governance that influences vulnerability to climate-led hazards. This complexity hampers effective responses to managing risk among policymakers and households (Elrick-Barr et al., 2014).

Climate change vulnerability is governed by a community's exposure and sensitivity to change and its adaptive capacity to anticipate, respond and recover from change (Adger, 2006). Exposure includes direct impacts, stresses and shocks to human and natural systems, including storms, cold, heat waves and drought. Sensitivity is affected by environmental degradation, socio-economic stresses, waste dumping and poor-quality drinking water and sewage disposal. Adaptive capacity depends on resource management, including hygiene in slum areas.

In order to be successful, adaptive planning need to include local people in decision-making and to conduct vulnerability assessments based on household characteristics and processes involved in adjustment. Households differ in vulnerability and decision-making ability, which can skew results or hamper adaptation strategies. For example, improving households' knowledge about climate risk may enhance adaptive capacity (Marshall et al., 2012), but limited capability to use this knowledge in decision making may limit its effect on capacity.

Several theoretical frameworks have been proposed to assess adaptive capacity (Smit et al., 1999; Adger et al., 2009; Gupta et al., 2010), but few empirical studies examine adaptation at community level (Wall and Marzall, 2006; Nhuan et al., 2016) or household level (Below et al., 2012; Pandey et al., 2016). Evidence shows that policy and planning should be based on household decision-making abilities and should seek to enhance these abilities (Pandey and Jha, 2012; Pandey et al., 2017). Households are rational decision makers, but their ability to make effective decisions differs depending on intrinsic qualities such as age, education, gender of the household head and possession of livelihood assets (Pandey et al., 2009). Therefore, in the present study a bottom-up approach (based on local people's perceptions) was used to assess the vulnerability and adaptation of slum dwellers. In particular, we analysed household ability and capability to make decisions under uncertainty and risk and to adopt strategies to reduce vulnerability to climate change. We also examined whether vulnerability and adaptation strategies differ within slum-dwelling communities and whether this influences the decision-making capability of poor households.

2. Study area

The study was conducted in Dehradun city, south-central Dehradun district (30°19′N, 78°20′E),in the foothills of the Indian Himalayas. This region has already experienced a temperature increase of 0.74 °C over the last 100 years, which exceeds the global average (Du et al., 2004; IPCC, 2007; Eriksson et al., 2009). Dehradun has seen an increase of 0.54 °C in the past 20 years (Singh et al., 2013). Dehradun is located on a north to south-southwest slope, at 640 m above sea level, and occupies approximately 67 km^2. The city is dissected by numerous seasonal streams and water channels (Roy, 2007). Dehradun was chosen because its size and geography make it a good proxy for other urban centres in the Indian Himalayas.

There are four seasons, winter (December–February), summer (March–May), monsoon (June–September) and post-monsoon (October–November). The summers are moderately hot, with average temperatures of 35–36°C rising to peaks of 41 °C. There are on average 1–2 days of extremely hot weather (max. temperature 4–6 °C higher than the seasonal average). Winters are mild, with fog and mist during nights and early mornings and few low-temperature (1–2 °C) days. The diurnal variation in temperature is around 9 °C during winter and rainfall is low. The monsoon typically starts in late June, but pre-monsoon rains can occur earlier. Mean annual rainfall is 2183 mm, with 87% falling during the monsoon season, particularly July and August (Sharma et al., 2012). The monsoon season has the highest relative average humidity (> 70%) and summer the lowest (45%) (Roy, 2007).

Dehradun city has a population of 570,000, with decadal growth of 29% in 2011. In 2011, the population density was 8633 individuals per km and the literacy rate was 88%.There are 102 slums, with 16,917 households housing0.12 million people (26% of city population) (Census of India, 2011). These slums have minimal civic facilities, with irregular water supply, no drainage, frequent water logging and narrow unpaved roads. Open defecation is common among slum dwellers, causing spread of disease. Waste is dumped openly in the street and organised solid waste collection is lacking (GHK, 2007).

3. Methods

Questionnaire-based interviews were conducted to obtain information about household-level adaptation to climate change in the slums of Dehradun city. The slum dwellers have low levels of education and are self-employed or depend on wage labour. They reside mainly in temporary structures with high occupancy and minimal municipal amenities. Four slum areas were chosen for data collection (Pounda, Patel Nagar, Bindaal and Risapana) based on size, population density and location (near to industry or commercial site; along seasonal water body) (Table 1; Fig. 1). Random sampling was used to select 121 households from these areas, as housing was more or less similar in all areas. The number of samples was based on the size of slum households and available resources for the survey. Following pre-testing, a survey questionnaire was used in face-to-face interviews with household heads in February–June 2016. Before the interviews, the respondents were briefed about the issue in the local language. Interestingly, these slum dwellers were relatively well informed about climate change and were aware of recent changes in precipitation, temperature and frequency of extreme events.

The survey was designed to assess different dimensions of household-level vulnerability and adaptive capacity. It assessed slum demography, general household information, three dimensions of vulnerability (exposure, sensitivity, adaptation) and coping options for addressing the impacts of climate change (Table 2; Fig. 2). Exposure to climate change included indicators or questions related to: climate variability, solid waste disposal and disaster impacts. Sensitivity included questions about major environmental, social and climate challenges currently faced by households and about the protective functions of households. Adaptive capacity included questions related to social networking, water availability, familial health status and hygiene management. The last section of the questionnaire addressed coping strategies, including indicators for provision of funds, material support for infrastructure, food availability, information and technology (Table 2). The questions were based on selected indicators or sets of indicators that served as proxies for the issues under consideration.

Table 1
Geographical information on the slum areas and households studied.

Slum area	Longitude	Latitude	No. of households surveyed
Bindaal	78°03′28″N	30°30′27″E	31
Risapana	78°05′78″N	30°29′51″E	36
Patel Nagar	78°01′56″N	30°30′86″E	40
Pounda	77°95′27″N	30°34′33″E	14

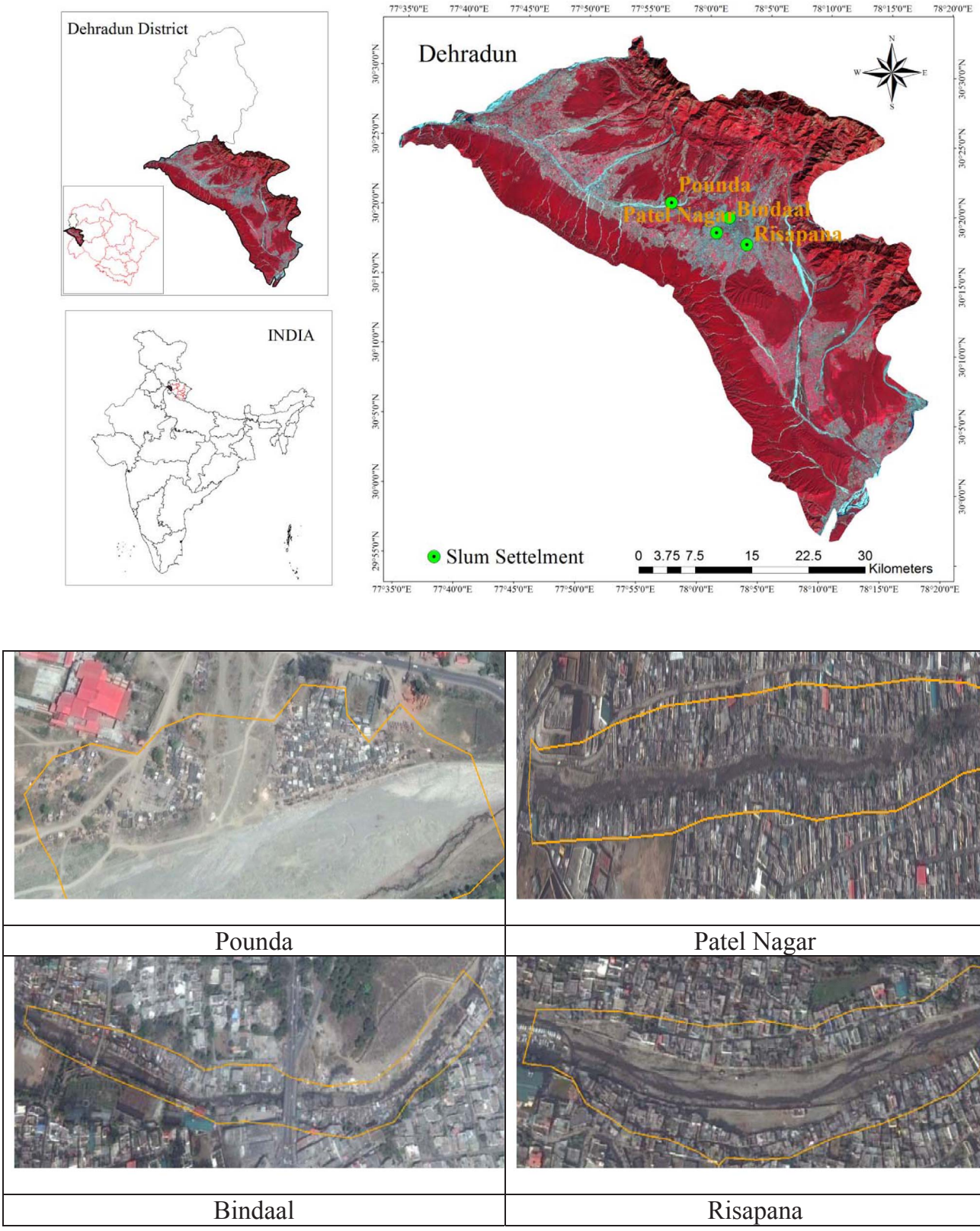

Fig. 1. Map of the study area in the Indian Himalayas, Dehradun district, and the four slum areas studied: Pounda, Patel Nagar, Bindaal and Risapana.

Household characteristics were classified into two broad categories, decision-making capability and resource capacity. The households were then divided into two groups per category (good and bad decision makers; poor households and poorer households). A decision-making capability index was estimated based on age (an indicator of experience) and gender (physical capacity to work) of the head of household, family education status (capacity to understand, appreciate and resolve the issue) and family size (caring and sharing of responsibility) using a previously tested framework (Pandey et al., 2009). A resource capacity index was estimated on the availability of movable

Table 2
Description of the dimensions and main components of vulnerability and of coping strategies.

Dimension	Main components	Description
Vulnerability		
Exposure	Climate variation	Exposure from variation in climate parameters
	Solid waste	Exposure from non-disposal of solid waste
	Human system	Stress due to diseases and health
	Natural system	Stress due to natural phenomena
	Disaster impact	Stress due to recent disaster
Sensitivity	Environment sensitivity	Sensitivity due to environmental impact
	Socio-economic sensitivity	Sensitivity due to socio-economic impact
	Household sensitivity	Sensitivity due to household assets
	Protective sensitivity	Sensitivity due to health impact
	Climate change sensitivity	Sensitivity due to impact of climate variation
Adaptive Capacity	Social network	Social relationships
	Water management	Water availability
	Health hazard	Disease prevention
	Hygiene management	Waste disposal
	Information barrier	Awareness
Coping strategy		
Coping Strategy	Fund support	Provision of fund or credit
	Material support	Provision of material for house building
	Food support	Provision of food
	Information support	Provision of information
	Technology support	Provision of technology for safety and comforts

assets within the household (e.g. television, freezer, cooler, rickshaw) and immovable assets such as house ownership, house type and location, electricity connection and in-house toilet facilities. The indicators for the parameters were standardised before the average based on the indicators for all parameters was estimated. The classes were then defined by considering half the maximum value for each category. For decision capability and resource capacity, the maximum value was 0.76 and 0.62, respectively, and therefore 0.38 and 0.31, respectively, was set as the threshold point for formation of the two groups in each category.

For comparisons between the two groups, t-tests for two independent samples were applied to:

$$H_0: \mu_1 - \mu_2 = 0$$

where H_0 is the null hypothesis of no significant difference between the two groups for the different parameters and dimensions of vulnerability at type-one error of 0.05,μ_1 is the mean of the parameter for good decision maker (or poor household) and μ_2 the mean for bad decision maker (or poorer household).

The analysis of the vulnerability assessment data was based on a bottom-up approach, with individuals seen as dynamic entities and part of a socio-ecological system. These individuals have the capacity to learn, mediate, accumulate, modify and adjust according to knowledge gained based on their interactions and observations within the community and with other components of their society. This approach assessed household responses to site-specific, socio-economic and biophysical indicators contributing to vulnerability and coping strategies and derivation of measures for the desired entity, e.g. vulnerability and its components. Lesson learnt on development of indices in previous studies were also applied (Urothody and Larsen, 2010; Pandey and Jha, 2012; Pandey et al., 2016).

Coping strategies and dimensions of vulnerability were determined based on a set of five components (Table 2; Appendix I), using indicators from the literature on climate change impacts with particular focus on poor and/or mountainous regions (Pandey and Jha, 2012; Matyas and Pelling, 2012; Pandey et al., 2016, 2017).

The indicators and components were brought to comparable levels through a min-max or max-min normalisation approach (Pandey et al., 2016), according to their functional links with the indicators and associated functions. The standardised indicators of the components were then averaged, as were all components of the coping strategies and the respective dimension of vulnerability. The value of each dimension of the coping strategies and vulnerability ranged between 0 and 1. Vulnerability was estimated as the average of the three dimensions (exposure, sensitivity, adaptive capacity). All dimensions and components were given similar weighting. Having equal numbers of main components facilitated estimation of climate vulnerability index (CVI) and coping strategy under current stress (CSCS), calculated as:

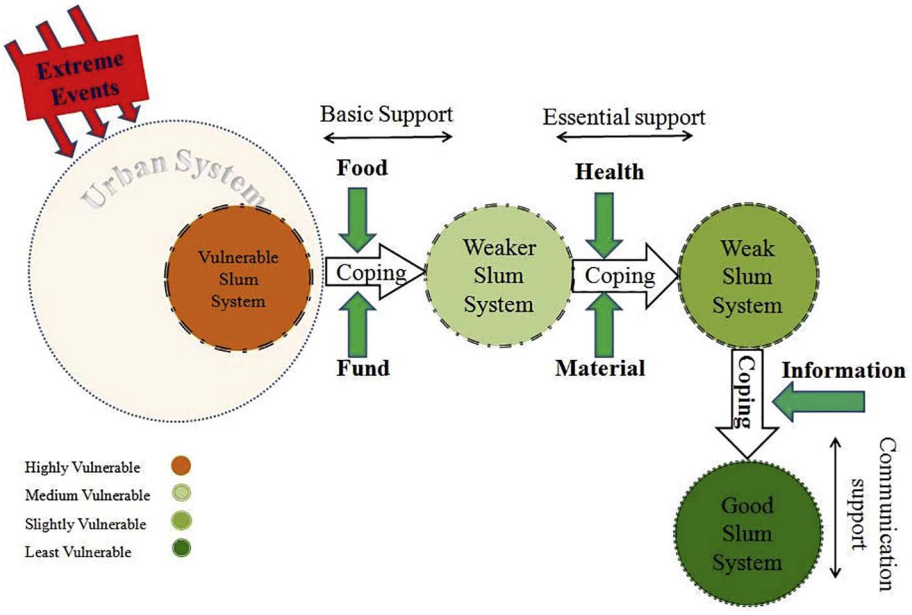

Fig. 2. Schematic diagram for reduction of vulnerability in urban slum system under support mechanism.

Table 3
Status of vulnerability dimensions (exposure, sensitivity and adaptive capacity) and coping strategies in urban slums of Dehradun, Indian Himalayas.

Dimension	Main components	Mean ± SE	Mean ± SE
Vulnerability			
Exposure	Climate variation	0.56 ± 0.02	0.34 ± 0.01
	Solid waste	0.15 ± 0.02	
	Human system	0.31 ± 0.01	
	Natural system	0.48 ± 0.02	
	Disaster impact	0.20 ± 0.01	
Sensitivity	Environment sensitivity	0.50 ± 0.01	0.51 ± 0.01
	Socio-economic sensitivity	0.50 ± 0.01	
	Household sensitivity	0.57 ± 0.02	
	Protective sensitivity	0.52 ± 0.02	
	Climate change sensitivity	0.46 ± 0.01	
Adaptive capacity	Social network	0.51 ± 0.02	0.56 ± 0.01
	Water management	0.31 ± 0.04	
	Health hazard	0.67 ± 0.02	
	Hygiene management	0.34 ± 0.04	
	Information barrier	0.91 ± 0.02	
Vulnerability = 0.85			
Coping strategy	Fund support	0.82 ± 0.03	0.54 ± 0.01
	Material support	0.35 ± 0.01	
	Food support	0.91 ± 0.02	
	Information support	0.53 ± 0.03	
	Technology support	0.17 ± 0.01	

Overall Coping Strategy under Current Stress = 0.41

$$CVI = 1 - \left| \frac{Sensitivity - Adaptive\ Capacity}{Exposure} \right|$$

and

$$CSCS = 1 - |Coping\ Strategy + Adaptive\ Capacity - Sensitivity|$$

Theoretically, CSCS can account for reductions in vulnerability based on additional capacity with the support of supplementary inflows for adaptation strategies from external sources under the current climate change scenario. High CVI reflects high vulnerability.

4. Results and discussion

4.1. Description of slum areas

Respondent age ranged from 19 to 70 (mean 37 years). Most respondents were either the household head or its oldest member. Household size varied from three to 14 members (average seven members, four males and three females). Around 64%of households owned their houses, while the rest rented, and 68% of houses had mains electricity. Education level was very low, with only 3% of males and 2% of females having post-secondary education. Nearly 44% of males and 52% of females were illiterate and most households had only one profession for their livelihood. The primary professions were wage labour (45%), small shopkeeper (29%), self-employed (16%) and rack-picker (7%). However, 17% were rack-pickers (who make a living by rummaging through refuse in the streets to collect material for salvage) as a secondary profession. The number of days worked by labourers was below 20 days per month for 44% of the households. In general, employment was mainly through the informal economy, irregular and low-paid. Most households did not have immovable assets. Only 30% had a television, 37% had a hand-drawn, three-wheel rickshaw and 77% of households used kerosene for cooking (the rest used LPG). Only 34% had a tap for water, while 66% used a hand pump. The respondents bought food from markets and food sufficiency stock was less than one month. Nearly 62% of respondents had no street lighting and 73% lacked dustbins for their premises.

Almost all respondents reported open defecation in the area, although 47% of the households had in-built toilet facilities. Waste disposal systems were almost non-existent and pavements were generally muddy, giving a poor environment with unhygienic conditions. Dumped waste leaches toxins into the environment and provides a habitat for organisms that can act as vectors of disease (Davis, 2007).

4.2. Vulnerability and coping in slums

The selected slums were located along river banks, uninhabitable wasteland and waste dumping sites. The most important form of exposure was weather variations, followed by impacts due to extreme events such as drought, floods and cold. The respondents had seen changes in climate, with around 76% dwellers reporting higher temperatures and number of hot days in recent years and around 52% reporting decreased precipitation and number of cold days. Moreover, around 68% and 44% of household reported lower water availability during summer and winter, respectively. Increased severity of drought and floods was reported by 48% and 31% households, respectively. However, 48% of households reported decreased severity of cold.

There was a low level of exposure due to disasters, probably due to low incidence and short duration of disasters, but any disaster was still important due to respondents' poor economic conditions. Due to extreme events, especially flooding, 21% of households surveyed reported losing their house and another 33% reported damage to their house. About 50%ofhouseholds reported losing income sources due to flood, 15% due to cold and 19% due to drought. Loss of income is a major concern for slum dwellers. Around 46% of households said they faced health-related problems due to cold, 30% due to flood and 25% due to drought. Around 39% reported that flooding had disrupted their children's education. There was some exposure to solid waste, probably due to living conditions in the slums, combined with poor hygiene conditions since childhood.

Importantly, all sensitivity factors, ranging from the environment to socio-economic conditions, were rated highly by the inhabitants. Hazards to health, most likely due to poor hygiene, also affected their adaptive capacity. The high information barrier resulted in a low level of awareness with regard to hygiene and changes in climate. The overall vulnerability was very high (Table 3).

Similarly to urban slum-dwellers in Manila (Alcayna-Stevens, 2015), the slum dwellers surveyed had low absorptive and coping capacity for extreme weather events. This was probably why the respondents wanted assistance in strengthening their resource base for adaptive capacity to climate change. Such assistance could be based on external support such as funding, materials, food, information and technical support. The slum dwellers were especially enthusiastic about food support (Table 3). This reflects the overall low standard of welfare in respondents' household sand was also apparent when discussing food sufficiency. Funding was seen as very important, as households were unable to earn sufficient for food and their other basic requirements. They expressed a low need for technological support, primarily because their basic requirements can be met without technical equipment. However, they wanted to receive information about making appropriate adjustments to stresses (Table 3).

4.3. Differential vulnerability and coping in slums with respect to household characteristics

Key components of the dimensions of vulnerability and coping strategies differed with the economic status and decision-making capability of the slum households surveyed (Tables 4 and 5). The exposure dimension of vulnerability differed significantly by asset capacity and decision capability (Table 5). It was expected that better internal and external household resources, such as educational status and livelihood options, would result in differentiated evaluation of climate parameters. However, there were no significant differences between poor and poorer households, or between good and bad decision makers, for any individual component of exposure except climate variation and disaster impact, which differed significantly between the two decision

Table 4
Comparative analysis of the main components of vulnerability and coping strategies based on decision capability and resource capacity among the slum dwellers.

Indicator	Decision capability			Resource capacity		
	Class	Mean ± SE	t-value (P-value)	Class	Mean ± SE	t-value (P-value)
Vulnerability parameter						
Climate variation	Good (53)	0.49 ± 0.02	5.15 (0.00)	Poorer (48)	0.59 ± 0.02	1.25 (0.22)
	Bad (69)	0.62 ± 0.02		Poor (74)	0.55 ± 0.02	
Solid waste	Good (53)	0.11 ± 0.03	1.45 (0.15)	Poorer (48)	0.19 ± 0.04	1.58 (0.12)
	Bad (69)	0.17 ± 0.03		Poor (74)	0.11 ± 0.03	
Human system	Good (53)	0.31 ± 0.02	0.19 (0.85)	Poorer (48)	0.32 ± 0.02	0.78 (0.44)
	Bad (69)	0.31 ± 0.02		Poor (74)	0.31 ± 0.01	
Natural system	Good (53)	0.44 ± 0.03	1.74 (0.08)	Poorer (48)	0.50 ± 0.03	0.98 (0.34)
	Bad (69)	0.51 ± 0.03		Poor (74)	0.46 ± 0.03	
Disaster impact	Good (53)	0.22 ± 0.01	3.44 (0.01)	Poorer (48)	0.20 ± 0.01	0.04 (0.98)
	Bad (69)	0.18 ± 0.01		Poor (74)	0.20 ± 0.01	
Environment sensitivity	Good (53)	0.50 ± 0.00	1.88 (0.07)	Poorer (48)	0.50 ± 0.00	0.79 (0.44)
	Bad (69)	0.50 ± 0.00		Poor (74)	0.50 ± 0.00	
Socio-economic Sensitivity	Good (53)	0.50 ± 0.00	1.5 (0.14)	Poorer (48)	0.50 ± 0.00	1.36 (0.18)
	Bad (69)	0.51 ± 0.00		Poor (74)	0.50 ± 0.00	
Household sensitivity	Good (53)	0.59 ± 0.03	0.82 (0.41)	Poorer (48)	0.57 ± 0.02	0.02 (0.99)
	Bad (69)	0.56 ± 0.02		Poor (74)	0.57 ± 0.02	
Protective sensitivity	Good (53)	0.54 ± 0.03	8.0 (0.43)	Poorer (48)	0.53 ± 0.03	0.33 (0.75)
	Bad (69)	0.50 ± 0.03		Poor (74)	0.51 ± 0.03	
Climate change sensitivity	Good (53)	0.46 ± 0.02	0.15 (0.89)	Poorer (48)	0.46 ± 0.02	0.18 (0.87)
	Bad (69)	0.46 ± 0.01		Poor (74)	0.46 ± 0.02	
Social network	Good (53)	0.49 ± 0.03	1.13 (0.27)	Poorer (48)	0.49 ± 0.02	1.12 (0.27)
	Bad (69)	0.52 ± 0.02		Poor (74)	0.52 ± 0.02	
Water management	Good (53)	0.34 ± 0.06	0.57 (0.58)	Poorer (48)	0.35 ± 0.07	0.88 (0.39)
	Bad (69)	0.29 ± 0.05		Poor (74)	0.28 ± 0.05	
Health hazard	Good (53)	0.72 ± 0.03	1.68 (0.09)	Poorer (48)	0.64 ± 0.04	1.08 (0.29)
	Bad (69)	0.63 ± 0.03		Poor (74)	0.69 ± 0.03	
Hygiene management	Good (53)	0.32 ± 0.06	0.55 (0.59)	Poorer (48)	0.36 ± 0.06	0.45 (0.67)
	Bad (69)	0.36 ± 0.06		Poor (74)	0.33 ± 0.05	
Information barrier	Good (53)	0.87 ± 0.03	2.46 (0.02)	Poorer (48)	0.94 ± 0.02	1.15 (0.26)
	Bad (69)	0.95 ± 0.02		Poor (74)	0.90 ± 0.02	
Coping strategy parameter						
Fund support	Good (53)	0.82 ± 0.03	1.0 (0.93)	Poorer (48)	0.83 ± 0.04	0.28 (0.79)
	Bad (69)	0.83 ± 0.04		Poor (74)	0.82 ± 0.04	
Material support	Good (53)	0.31 ± 0.01	4.6 (0.00)	Poorer (48)	0.39 ± 0.01	3.82 (0.00)
	Bad (69)	0.38 ± 0.01		Poor (74)	0.32 ± 0.01	
Food support	Good (53)	0.90 ± 0.03	0.41 (0.69)	Poorer (48)	0.95 ± 0.02	1.68 (0.10)
	Bad (69)	0.91 ± 0.03		Poor (74)	0.88 ± 0.03	
Information support	Good (53)	0.41 ± 0.05	3.6 (0.01)	Poorer (48)	0.61 ± 0.04	2.41 (0.02)
	Bad (69)	0.62 ± 0.04		Poor (74)	0.47 ± 0.04	
Technology support	Good (53)	0.17 ± 0.00	0.88 (0.39)	Poorer (48)	0.17 ± 0.00	0.81 (0.43)
	Bad (69)	0.17 ± 0.00		Poor (74)	0.17 ± 0.00	

capability groups (Table 4). This was largely due to the subsistence nature of livelihood options such as mixed farming, which is primarily governed by climate. Interestingly, there were no significant differences in the sensitivity dimension of vulnerability (Table 5) and its various components between any of the groups (Table 4). Thus, there were no marked differences in the rating given by slum dwellers in the two pairs of groups as far as household and environmental sensitivity were concerned (Table 5). This shows that the internal and external conditions of the households were more or less similar for overall household welfare mechanisms.

The adaptive capacity dimension of vulnerability differed depending on decision-making capability grouping, while resource

Table 5
Comparative analysis of overall vulnerability and coping strategies based on decision capability and resource capacity among the slum dwellers studied.

Indicator	Decision capability			Resource capacity		
	Class	Mean ± SE	t-value (P-value)	Class	Mean ± SE	t-value (P-value)
Exposure	Good (53)	0.31 ± 0.01	3.49 (0.00)	Poorer (48)	0.36 ± 0.01	2.41 (0.02)
	Bad (69)	0.36 ± 0.01		Poor (74)	0.33 ± 0.01	
Sensitivity	Good (53)	0.52 ± 0.01	1.32 (0.19)	Poorer (48)	0.51 ± 0.01	1.23 (1.00)
	Bad (69)	0.50 ± 0.01		Poor (74)	0.51 ± 0.01	
Adaptive capacity	Good (53)	0.52 ± 0.02	2.78 (0.07)	Poorer (48)	0.59 ± 0.02	0.47 (0.65)
	Bad (69)	0.58 ± 0.02		Poor (74)	0.53 ± 0.02	
Vulnerability	Good (53)	0.62 ± 0.03	0.83 (0.41)	Poorer (48)	0.66 ± 0.04	0.75 (0.45)
	Bad (69)	0.67 ± 0.05		Poor (74)	0.63 ± 0.04	
Coping strategy	Good (53)	0.54 ± 0.02	0.26 (0.80)	Poorer (48)	0.56 ± 0.02	2.58 (0.02)
	Bad (69)	0.55 ± 0.02		Poor (74)	0.54 ± 0.02	
Coping strategy under current stress	Good (53)	0.45 ± 0.03	2.03 (0.04)	Poorer (48)	0.36 ± 0.03	1.75 (0.08)
	Bad (69)	0.37 ± 0.03		Poor (74)	0.43 ± 0.02	

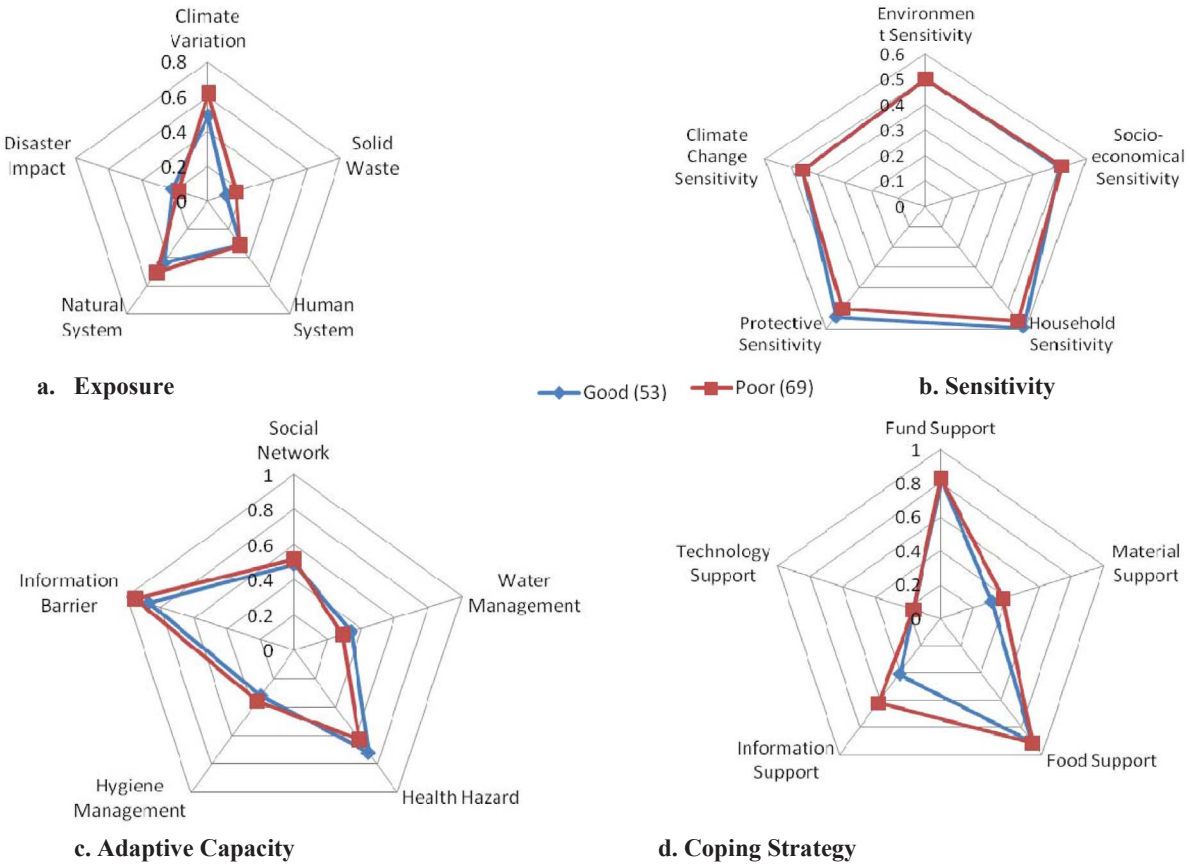

Fig. 3. Spider diagram of different components of vulnerability and coping strategies with respect to household decision-making capability.

capacity did not influence the adaptive capacity of slum dwellers (Table 5). The adaptive capacity differed between the groups of decision makers for information management and health management, while social networking, water management and hygiene management were similar for both groups (Table 4). The bad decision makers had restricted access to information, largely due to their poor information channels compared with good decision maker households (Table 4 and Fig. 3). The better information sources of the latter were possibly due to differences in social contacts between the groups, leading to differences in information generation through networking.

The components of the coping strategies differed between the decision-making capability and resource capacity groups of slum dwellers; poorer respondents had better materials and information support (Table 5), while bad decision makers had better materials and information support than good decision makers. The higher support in terms of building materials for poorer households and bad decision maker households may be because of their relatively lower quality demands on materials for house building and their strong association with their residential location (Table 4). Alternatively, external provision of materials may be targeted more strongly by households that are relatively sound in terms of economic and social contacts (Table 4; Figs. 3 and 4).

The coping strategy of the slum dwellers was also assessed based on external funding support or provisions for loan sand technology uptake, but no significant differences in these two components of coping strategies were found between the pairs of groups (Table 4). Thus, it can be argued that the resource capacity and decision-making capability of the households did not affect the fund flow mechanism and technology uptake within the slum dweller population studied. This may be due to the low variation in funding and technology uptake between the groups studied. The other potential reason may be very low penetration of technology and low funding disbursement due to poor loan repayment capacity of the households. External support follows strict regulations for funding and technical criteria and is channelled through e.g. a bank or other organisation. The food requirement was consistent for all groups and did not contribute directly to formulating coping strategies. Therefore, food support from other sources did not upgrade the communities based on their economic and social differences. Moreover, most of the households were positive to food support. Our analytical approach did not allow us to investigate the causation. The similarity in coping strategy components between the groups perhaps ultimately reflects the poor developmental processes prevalent in these slum areas.

5. Conclusions

Compounding relationships between the vulnerability of slum dwellers, a degraded environment and higher disaster risk were apparent and prevalent in the slum areas studied. Poverty, with reliance on limited employability, generates pressure on household functioning and welfare. Poor natural and human conditions reduced the coping capability of the slum dwellers surveyed.

We found that vulnerability and coping strategy can be socially differentiated in terms of the decision-making capability and resource capacity of households. The level of vulnerability or risk was not similar in all slum households; the decision-deficient and/or resource-poor suffer disproportionately from the consequences of stresses such as climate change. Increased understanding and awareness of these households would help them reduce the impacts of climate change by implementing precautionary measures. Moreover, better resource capacity would help them equip themselves for disaster responses. Future coping strategies must include information about disaster responses, mitigation strategies and material support for overall household welfare.

Effective programmes need to incorporate education, health

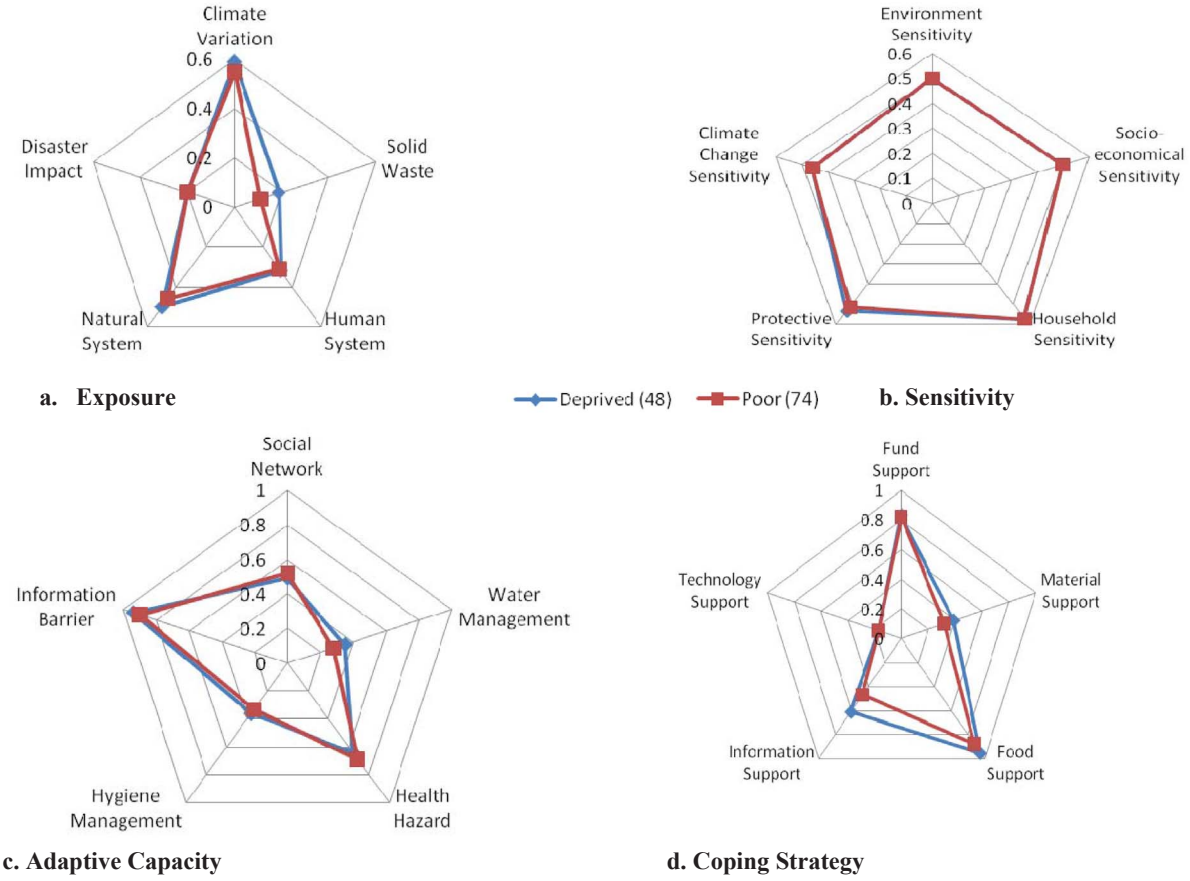

Fig. 4. Spider diagram of different components of vulnerability and coping strategies with respect to household asset distribution.

services and investments in urban infrastructure in order to help provide sustainable livelihoods for the urban poor. It is also important to resolve contamination and waste disposal, which impair living conditions and risk increasing the frequency of e.g. flooding and disease in the longer-term. The current inaction of city authorities and how slum dwellers interact with their environment increase the urban disaster risk in slums. Managing this risk requires more concerted municipal intervention and attention, especially with climate change predicted to increase extreme weather events.

The malignant trinity of rapid urbanisation, climate change and economic migration from rural areas is set to continue in developing countries and thus urban slums are likely to increase. It is therefore important to develop guidelines, policies and programmes ensuring sustainable urban development for all. Further work is needed to empirically evaluate the relationship between different indicators and coping strategies in response to climate change or extreme events in slum households.

Appendix

Questionnaire for household survey

QUESTIONNAIRE FOR HOUSEHOLD SURVEY

AUTHORIZATION: I have been informed about the study in detail. I know the possible risks and benefits. I know that being in this study is voluntary and anonymous. I choose to be in this study. I know that I can withdraw at any time. I agree/disagree to participate in the survey.

BASIC INFORMATION ON SLUM

Name of slum		**Landmark**	

Street light in the slum	Yes/No	**Provision of dustbin**	Yes/No	**Open defecation**	Yes/No

Type of area surrounding the slum	Residential/Industrial/Commercial/Institutional/Other

Physical location of slum	Along nallah/Along other drain/Along railway line/Along river/Along water body/Along road/Other

General Household Information About Respondent

Name of respondent		**Sex**	M/F	**Age**	

Family Size Distribution

Member	**Up to 18**	**19-36**	**37-54**	**Above 55**	**Migrated member**
Male					
Female					

Family Education Status

Education	**Illiterate**	**Primary**	**High school**	**Intermediate**	**Degree and above**
Male					
Female					

House	Own/Rented	**Type of House**	Pakka/Semi-pakka/Kachha	**Area of house**	

Number of rooms		**Electricity**	Yes/No	**Toilet**	In-house/Outside

Profession	Wage labour/Agriculture/Self-employed/Service/Shopkeeper/Rack-picker
How many days of work do you get?	

Household assets	TV	Fridge	Rickshaw	Cooler	Bike	None

Major cooking energy source	Kerosene	LPG	Heater	None

Source of drinking water	Tap	Hand pump	Heater	Open source

Drainage system	Organised	No drainage	Open and choked

Major food source	Market	Collection

Stocksof food	<1month	1-2months	>3 Months

Purification of water	No/Filtering/Boiling/Chemical treatment

Exposure

1. **Perception about climate parameters (Climate Variation)**

Perception about change in temperature	Increase/No change/Decrease
Perception about change in rainfall	Increase/No change/Decrease
Perception about change in number of hot days	Increase/No change/Decrease
Perception about change in number of cold days	Increase/No change/Decrease

2. **Perception about waste (Solid Waste Exposure)**

Disposal of waste	Open/Organised/Scattered
Frequency of disposal	Daily/Once every2 days/Once a week/Once every15 days/No collection

3. Impacts of climate change in the past 5 years (Human System)

Impacts	**Summer**	**Winter**	**Autumn**
Water availability	Increase/No change/Decrease	Increase/No change/Decrease	Increase/No change/ Decrease
Human health	Improved/No change/ Worsened	Improved/No change/ Worsened	Improved/No change/ Worsened

4. Impacts of changing climate in the past 5 years (Natural System)

Severity of drought	**Severity of flood**	**Severity of cold**
Increase/Nochange/Decrease	Increase/No change/Decrease	Increase/No change/Decrease

5. Impact of last natural disaster	**Drought**	**Flood**	**Cold**
Death of household member/s			
Missing household member/s			

Destroyed home completely			
Destroyed home partly			
Loss of domestic animals			
Loss of other income earning source			
Health hazard of family members			
Education of family members disturbed			

Sensitivity

1. What are the top three challenges that you currently face? (Please rank them from 1 to 3, with 1 being the most challenging).

Concern	Environmental	Economic	Social
Population pressure			
Health			
Developmental work			
Climate change			
Water quality			
Waste disposal			
Drainage			

2a. How would you rate the severity of the top challenge (chosen as number 1)? (Household Sensitivity)

Environmental	Not a problem	Slightly problematic	Moderate	Severe	Very severe
Economic	Not a problem	Slightly problematic	Moderate	Severe	Very severe
Social	Not a problem	Slightly problematic	Moderate	Severe	Very severe

2b. In your opinion, how serious is the problem of climate change? Climate change is:

Not serious at all	Somewhat serious	Serious	Very serious	Don't know

3. Perception about protective function

Protective function	Increased	Decreased	No change	Don't know
Disease incidence				
Insect incidence				
Food availability				

4. Have you developed plans to deal with the potential impacts from climate change?

Yes, am currently developing plans	Yes, am currently implementing plans	No	Don't know

5. Based on your knowledge and views, how might climate change impact upon your household?

Impacts	Very low possibility	Low possibility	Moderate possibility	High possibility	Don't expect to change	Don't know
More frequent local rainfall						
Less frequent local rainfall						
Decreased local water quantity						
Increased local air temperature						
Increased solid wastes						
Increased drainage problem						

Adaptive Capacity

1. Social network

a. Assistance obtained during crisis	Friends	NGOs	Government	No assistance
b. Assistance to others during crisis	Yes/No	**c. Member of social organisation**		Yes/No

2. Adjustment for water scarcity	Use underground water/Less water use/Bring from other places

3. Disease prevention (Health)	Use of net	Obtain government support	Cleaning the surroundings
	No prevention	Regular check-up	Spraying insecticide

4. Waste management (Hygiene)	Closed bins/Open dumping/Municipal support/Composting/Other

5. Awareness of respondent (Information)	Aware	Access to TV	Access to newspaper
	Access to representative	At least one source	No access to information

Coping Strategy

1. Fund support

Grants availability	Yes/No	Credit facility	Yes/No

2. Material support

Housing/Housing Materials	Yes/No	Sanitation facility	Yes/No

3. Food support

Food availability	Yes/No	Water availability	Yes/No

4. Information support

Information availability	Yes/No	Training facility	Yes/No

5. Technology

River training	Yes/No	Building embankments	Yes/No
Rising of roads	Yes/No	Homestead plinth raising	Yes/No

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